

ART. XX.—*Notes on Dust Whirls in Sub-Arid Western Australia.*

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Introduction.

Dust whirls are well known phenomena in arid and sub-arid countries. They are ascending spiral air currents, which also move in a linear direction, and which carry varying amounts of dust and fine sand with them.

Dust whirls have been well described by W. M. Davis¹ and by E. E. Free.² Davis points out³ that an inflow of air is begun towards the place of ascent, but as the various inflowing currents move for too short a distance to be systematically influenced by the earth's rotation, and as their irregular flow does not allow them to meet precisely at a centre, they turn a little to one side or the other, according as the stronger inflow decides, and a little whirl is then developed rotating indifferently one way or the other. Free also states⁴ that the rotation seems to be indiscriminately clockwise, or contra-clockwise, as frequently one as the other.

Dust whirls are recognised to be due to overheating of particular portions of the land surface, with the result that equilibrium is disturbed, and the air rushes upwards. The surrounding air then flows inwards, and a whirl is caused.⁵

Dust whirls have been recorded from various countries, and a valuable list of the literature has been given by Free in the work already cited.

Dust whirls may reach a considerable height. Thus Davis⁶ states they may reach a height of several hundred, or even a thou-

1. "Elementary Meteorology," 1894 p. 201.

2. U.S. Department of Agriculture, Bureau of Soils, Bulletin No. 68, 1911, p. 38, *et. seq.*

3. Loc. cit.

4. Loc. cit.

5. See Free, loc. cit.

6. Loc. cit.

sand, feet; and Free⁷ mentions that they are from a few feet to hundreds of feet in height. I. C. Russell remarks⁸ that these columns of dust are often 2000 or 3000 feet, or even more, high. At various heights, according to atmospheric conditions, the dust tends to spread out horizontally, and so becomes invisible.

Dust columns are slender. Free remarks that they are a few inches to several feet in diameter.⁹ Various observers have pointed out that when seen at a distance, they resemble water-spouts, and that they mostly occur in calm summer weather.

Previous Australian Literature.

Of Australian occurrences, the writer has found few records.

D. W. Carnegie¹⁰ briefly refers to the occurrence of "willy-willies" in arid Western Australia, and states they are sometimes of great violence. J. W. Gregory, with regard to Central Australia, refers to the "dark whirling pillars of sand which slowly travelled up the valley"; also to "three tall columns of dust which were travelling straight towards us"; and again, to "the dust travelling chiefly in two whirlwinds."¹¹ D. Mawson has described¹² the "willy-willy" of the Broken Hill district, pointing out that they are of the nature of small cyclones, like water-spouts in outline, and that they are columns usually about 20 feet in diameter, rising to a height of several thousand feet. A. Montgomery has remarked¹³ in connection with the Western Australian goldfields country, that "on any fine day in summer it is quite usual to be able to see several whirlwind clouds of dust dancing over the landscape at one time."

These are the only Australian records that the writer is aware of.

In sub-arid Western Australia dust whirls are locally known as "willy-willies." They are a matter of common knowledge, but no precise description has, so far as the writer is aware, ever been given of them, and still less is there any record of their mode of rotation, their height and other characters. Even in Australia

7. Loc. cit.

8. Monograph XI., U.S. Geol. Surv., Washington, 1885, pp. 9 and 154.

9. See also Mawson's estimate mentioned below.

10. "Spinifex and Sand," London, 1898, pp. 254 and 274.

11. "The Dead Heart of Australia," London, 1906, pp. 26, 120, 121.

12. "Geological Investigations in the Broken Hill Area," Mem. Roy. Soc. South Aust., Vol. II., Part 4, 1912, p. 227.

13. "The Significance of Some Physiographical Characteristics of Western Australia," Journ. Roy. Soc. W. Aust., Vol. II., 1915-16, p. 83.

as a whole, the records, as noticed above, are scanty. Under these circumstances, some details, which were noted by the writer whilst engaged in geological work in the Niagara-Kookynie district, and, later, in the Comet Vale-Goongarrie districts¹⁴ may be worthy of record. The following notes are, therefore, based on such observations, and relate only to the districts mentioned:—

General Description.

In the districts just mentioned, the climate is sub-arid, and the average rainfall is about 10 inches, or slightly less, per annum. Except on the surfaces of the "dry" lakes, there is generally some vegetation, but there is much bare ground between the individual plants.

The dust whirls vary much in height, and perhaps in diameter. Many are but a few feet in height and in diameter, whilst others are hundreds, and probably thousands, of feet high, and perhaps of considerable diameter. The writer, however, has no criteria as to the diameter of the high whirls, but in all instances, the diameter is small compared with the height. The dust whirls are essentially moving columns or pillars. The whirls (as the table below shows) rotate clockwise (that is, in the direction north, thence east, thence south, and thence west), and anti- or counter-clockwise. The anti-clockwise direction predominates on the records obtained. A change from one mode of rotation to the other in the same dust whirl has been noticed, and such change has taken place more than once in the same whirl.

High dust whirls may be practically vertical, or curved, or bent at a high angle to the ground. The curving, or bending, doubtless indicates varying wind velocity at different altitudes.

The dust whirls travel in different linear directions across the country. This linear movement is usually rapid in whirls that are close to the observer. It is difficult to form an opinion about the velocity of distant whirls, and no estimate has been made by the writer as to the actual velocity of near-by whirls. A low whirl, as a rule, dies out within a minute or two, but a high whirl may be visible many minutes, or possibly some hours.

A dust whirl, even a very small one, is quite violent in its action. Dust, sand, grit, and old tins and other rubbish are lifted from, or driven along the ground with great force. When taken

14. The Niagara-Kookynie area is about 115 miles, and the Comet Vale-Goongarrie area about 60 miles north of Kalgoorlie.

unawares by a small dust whirl, one at first receives the impression of the sudden and violent rising of a great wind.

Red is the predominating colour of dust whirls, owing to red being the predominating colour of the soils.

The whirls are commonest in summer, on calm days, or on days with only a gentle breeze. These facts agree with the observations of investigators in other countries. After midday is the most favourable period for the occurrence of dust whirls.

Table of Observed Dust Whirls.

The following list comprises the dust whirls recorded by the writer in the Niagara-Kookynie and Comet Vale-Goongarrie districts, with the dates of occurrence, the direction of rotation, and general remarks. Where it was impossible—mainly on account of distance—to determine the direction of rotation, a blank has been left. In some cases, the direction given is not quite certain, hence a query has been added so as to express this doubt. One gigantic whirl has been separately described below on account of its special interest. The writer is well aware that the remarks as to height and other characters of individual whirls are vague, but the phenomena do not readily lend themselves to accurate measurements, and opportunity did not always permit of more definite statements:—

Date.		Direction of Rotation.	General Remarks.
1914.			
Dec. 18.	- -	Anticlockwise	These occurred in the Niagara-Kookynie district.
„ 18	- -	Clockwise	
„ 21	- -	Anticlockwise	
1915.			
Jan. 8	- -	Anticlockwise	No details, except direction of rotation were noted,
Feb. 10	- -	Clockwise	
„ 13	- -	Anticlockwise	
„ 23	- -	Anticlockwise	
Mar. 29	- -	Anticlockwise	Distant. In front of a ridge. From probable height of latter, the dust whirl was estimated to be 1000 feet high at the least. East of Kookynie.
„ 15			
1916.			
Sept. 22			Distant.
„ 22			Distant.
„ 25	- -	Anticlockwise (?)	Low. ¹⁵ On ironstone country.

15. "Low" means that the dust whirl as seen by the naked eye reached to only a small height from the surface of the ground, in some instances, not more than 20 feet, and even less.

Date.			Direction of Rotation.	General Remarks.
Nov. 11	-	-	Anticlockwise	Low.
Dec. 5	-	-	Anticlockwise (?)	Distant. Fairly high.
„ 6	-	-	Anticlockwise	Fairly high.
„ 9	-	-	Anticlockwise	Low.
1917.				
Jan. 26				Distant. Hundreds of feet high. Thin, sandy-coloured column. Rapidly changed its form and density. Quickly became invisible. Noted at 3 p.m. on very calm day.
Feb. 6				Hundreds of feet high. Soon became invisible. Day calm and hot. Noted at 1 p.m.
„ 6	-	-	Anticlockwise (?)	Hundreds of feet high. Bent in the centre. Visible for a few minutes. Gradually faded away. Noted at 2.30 p.m.
„ 8	-	-	Anticlockwise (?)	Distant. Very high. Very distinct, so must have been carrying much dust.
„ 8				Ditto.
„ 8	-	-	Anticlockwise	Low. Raised considerable quantity of dust. Soon died out.
„ 12	-	-	Anticlockwise	Low. Soon died out.
„ 15	-	-	Clockwise	Low. Passed through camp. Lifted fine sand very strongly. Soon died out. About six feet in diameter.
„ 16	-	-	Anticlockwise	Each raised much dust, but soon died out. Diameter of each probably only a few feet.
„ 16	-	-	Anticlockwise	
„ 17	-	-	Clockwise	Low. A few feet in diameter.
„ 17	-	-	Anticlockwise	Low. A few feet in diameter. Soon died out.
„ 17				Some distance away. Probably at least 100 to 200 feet high.
„ 19	-	-	Clockwise	Low. Only about two feet in diameter.
„ 19	-	-	Clockwise	Low. Only about four feet in diameter.
„ 19	-	-	Clockwise and Anticlockwise	Somewhat higher than last two. Rotated both clockwise and anticlockwise, the change taking place more than once in a distance travelled of 50 or 60 yards. Diameter about 15 feet.

Date.		Direction of Rotation.	General Remarks.
Feb. 19			A gigantic dust whirl. Described separately below. Note.—The 19th February was a typical day for dust whirls, being hot and sultry, with a gentle N. to N.W. breeze. Those recorded were all in the afternoon.
Feb. 20			Low.
„ 26			A gigantic distant whirl. Must have been hundreds, or perhaps thousands, of feet high. Very dark-coloured and dense-looking. Visible for about five minutes, and appeared to be moving slowly southwards. The summit of the column of dust was clearly seen to be spreading out horizontally, as such columns do.
„ 27	- -	Anticlockwise	Low.
Mar. 1			Some miles distant. High, with apparently a fairly large diameter. Travelling southwards..
„ 1			A very high thin column.
„ 29	- -	Clockwise and Anticlockwise (?)	Low. On samphire flat.
„ 29			Low. On samphire flat.
„ 29			Low.
„ 29			Low.
May 8	- -	Clockwise and Anticlockwise (?)	Rather low. Raised much dust.. Travelling northwards. Travelled for a distance of about half a mile while visible. Direction of rotation almost certainly changed from clockwise to anticlockwise, and vice-versa.

Note.—The dust whirls recorded from 22nd September, 1916, onwards, occurred in the Comet Vale-Coongarrie district.

Summarising the above table records a total of 43 dust whirls. Of these 15 have no record as to direction of rotation, 15 are anti-clockwise, four are anti-clockwise with a query, six are clockwise, one is and two probably are both clockwise and anti-clockwise. The anti-clockwise rotation, therefore, predominates. This result could hardly be expected, for if, as appears to be the case, the whirls are of the nature of small cyclones, then in the southern hemispheres, the predominant rotation would be expected to follow

that of the normal cyclones, that is, clockwise. Further observations, however, are required, as the records in this paper are too few to come to a definite conclusion on the point raised.

A Gigantic Dust Whirl.

The whirl now to be described has been noted in the above list, but its occurrence was so striking that a separate description is warranted.

This dust whirl was observed on 19th February, 1917, at about 1.30 p.m., in the Comet Vale-Goongarrie district, when the sun had not passed a great distance beyond the zenith. The day was hot and sultry, with a gentle north to north-west wind. The conditions were, therefore, favourable for dust whirls. This particular whirl formed a great column of dust, the top of which was above two clouds, which were at different levels in the atmosphere, the difference of level apparently being considerable. These clouds were of the cumulus type, and were such as may be commonly observed in the area after midday under the conditions mentioned. The dust column was broken by these two clouds. The column was travelling southward, or south-westwards, at a fairly rapid rate, but the rate of motion could not be determined, and in doing so, passed beyond the clouds, and showed itself as one unbroken, gigantic column, with a pronounced bend forward (i.e., in the direction of its linear movement) at the top. Otherwise it appeared to be approximately vertical. The dust whirl was close to the path of the sun's rays, and as the sun was obscured by the upper cloud, the phenomena could be closely watched. The dust was dull, red in colour, and between the two clouds dense masses of dust could be seen by the naked eye whirling about and springing upwards. As it moved in the direction mentioned, the column became invisible within a few minutes. The direction of rotation could not be ascertained, nor could any idea be formed of its diameter, although the diameter appeared to be about the same through the whole length of the column.

The angle of elevation of the top of the column was guessed to be about 80° , but the horizontal distance of the column from the point of observation could not be ascertained, so that it is impossible to state its height, even very approximately. Judging by observation, it would certainly not be less than one mile distant, and probably much more; but if it be assumed that the distance was

one mile, that the column was approximately vertical, and that the angle of elevation was 80° , the dust whirl would be not far short of six miles in height; and if it were only half a mile away (which, however, seemed altogether too short a distance), the height would approximate towards three miles.

These figures are probably far too high, due, perhaps, to the assumption that the dust column was approximately vertical. The column might appear to be vertical, and yet could perhaps be much bent towards the observer. This would materially reduce the figures.

Another means of checking the height is to ascertain the height of either of the two clouds associated with the dust columns, but no data have been obtained for this. These clouds were two of many similar scattered over, all apparently of moderate height. Again, if the general average height that these clouds form at were known, an idea of the height of the dust whirl would be obtained, but there appears to be hardly any information available as to such clouds in Australia in this connection. Records of other countries show that the upper surfaces of cumulus clouds may be over 3000 feet high.¹⁶ There can be no doubt, however, that this particular dust whirl was of great height, reaching probably to several thousands of feet above the earth's surface, and the quantity of dust raised must have been enormous. When first viewed close to the sun's rays, the dust whirls presented a majestic spectacle.

The writer is indebted to Dr. Griffith Taylor for a reference to Mr. Quayle's Memoir on Clouds, and for some information concerning clouds, which he kindly obtained from Mr. Quayle.

Dust Whirls in Relation to Erosion.

Dust whirls must play an important part in the erosion of sub-arid Western Australia. From the preceding table it will be recognised that they are fairly numerous, even in a small area, and that they include columns of dust of great height. It must also be remembered that, unless high, numerous whirls, even comparatively close to an observer, are not seen by him. If the whole of the sub-arid portions of the State be considered, a vast amount of fine sand and dust must be displaced even in the course of one favourable day. The material is either lifted well into the air, or is dragged along or kept close to the surface of the ground. In the former case the material is chiefly fine dust, and in the latter

16. Davis. Op. cit., pp. 179 and 180.

case, which has been described as a saltatory action, fine sand. The fine dust tends to rise high into the air, and it may be some time before it settles down to the ground again. During this period it may travel far, and there can be no doubt that a considerable portion of it is carried beyond, or "exported" from the sub-arid areas.

In this way the general surface of these areas as a whole tends to be lowered.¹⁷ The dust which falls in other portions of these sub-arid areas, tends to increase the thickness of soils locally, and also to make these soils of a more heterogeneous character.¹⁸ Such soils are of course subject to removal by dust whirl and other aeolian action, as well as by rain action, but certain areas may receive more wind-blown material than they lose by the same agency.

The fine sand removed by saltatory action immediately settles again when the dust whirl dies out, but during its journey it would tend to collect and to remain in hollows. There is thus probably a general drift from the higher to the lower country (with some exceptions), which aids in keeping the general surface level, and thus in the formation of a vast high level plain—the "new plateau" of the writer.¹⁹

An interesting account of a dust-storm in south-western North America, and an estimate of the amount of dust precipitated have been recently given.²⁰ It has been concluded that owing to strong convectional air currents, "an enormous quantity of dust must have been eroded from these arid regions—(New Mexico and Arizona)—lifted into the upper atmosphere, and carried with the storm a thousand miles or more to the north-east, where it was brought down by the snow and sleet, which had formed at a great altitude in the air." It was calculated that not less than a million tons of organic and inorganic material fell, and probably many times that amount. The dust whirls discussed in this paper cannot of course be compared, from an erosional point of view, with such a storm, but nevertheless, the difference is but one of degree.

17. This idea of "exportation" has of course been brought forward by earlier writers, such as von Richthofen and Davis.

18. The mixed character of soils owing to the action of the wind generally has been fully described by Free. *Op. cit.* p. 109.

19. Bull. 61, Geol. Surv. W. Austral., Perth, 1914, p. 525.

20. See "Geographical Review," December, 1918, pp. 514 and 515.